

I. The Remote Sensing of Mineral Aerosols and their Impact on
Phytoplankton Productivity. Neil W. Tindale, Texas A&M University.

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[NAGW-3652]

Our original proposal was to use satellite data to help study the transport and input of mineral aerosol material to the remote open ocean and its impact on primary productivity in the surface waters. Understanding the transport and input of dust to the world's oceans is important not only for micronutrient input but also for calibrating the mineral aerosol contribution to the ocean floor sediment record. A side goal of our proposed study was to look at the contribution of aerosols to the ocean color signal as seen by the sensor. Our overall objectives involved participation in a number of field projects, both cruises and land based, in addition to the remote sensing. The funding we received from NASA mainly covered the acquisition and use of satellite data, and provided general support for two students, one of whom is still finishing his degree. The expenses associated with the actual field work were/are covered as parts of other grants from NSF, ONR, and the Australian Government.

In our original proposal to NASA we planned to participate in three field programs: the Galapagos Islands "Iron Patch" experiment; the JGOFS Arabian Sea experiment; and the IGAC ACE-1 Southern Ocean experiment. Data collected during these three experiments would aid us in our comparison between dust input and productivity, as well as provide atmospheric data from three distinctly different regions for use in the calibration of SeaWiFS. Overcoming the concern of one of the reviewers of our initial proposal, that the "proposal hinges on three large programs, of which two may not come off during FY-93 to FY-96", we have essentially completed the tasks that we had originally proposed. We successfully participated in one of the cruises of the Galapagos Island - "Iron Patch" experiment and completed the last cruise of the 1995 JGOFS Arabian Sea field work in early January. The timing for the ACE-1 field work had been delayed until November-December 1995 and we participated in both shipboard and land based atmospheric and oceanographic sampling as part of that program. Our field work on Macquarie Island, south of Tasmania, is still operational and will not be completed until the end of this year.

The above work report of course ignores the fact that SeaWiFS is still not operational [as of August, 1996] and that obviously we haven't been able to integrate the SeaWiFS data into our studies as was originally planned! We had hoped that the SeaWiFS satellite would have been launched in time to support at least some of our field work but now expect a launch date of

sometime in early 1997? So that even though our field work at Macquarie Island is still continuing [as of August, 1996], we do not expect the satellite to be operational before the end of this experiment. Brief details of the three field programs and our progress are included below.

Galapagos IronEx/PlumEx Experiments:

The overall objective of this experiment was to test the iron hypothesis; does the addition of iron to nutrient rich surface waters enhance productivity? Preliminary results from this experiment (Martin et al., 1994) lend support to this hypothesis; that the addition of iron to open ocean surface waters can affect primary productivity. This is a significant result with regard to the justification for our study on the importance of mineral aerosol input on primary productivity. Obviously in the Galapagos experiment there was an artificial addition of iron to a very small area, however the results have important implications regarding the possible role of atmospheric micronutrient material on a global-ocean scale.

Our specific objectives in this experiment included sampling and studying the marine aerosol size and type (which are related to chemical reactivity) during the PlumEx cruise to determine the importance of local (Galapagos Islands) versus long-range sources of atmospheric material. We also eventually hope to determine the optical properties of the stored aerosol samples that were collected during the cruise. Detailed results of single particle analysis of our samples are being prepared for publication in two papers. The first paper on microprobe analysis of aerosol particles (Seymour and Tindale, 1996), is being submitted this summer. [This paper has been reviewed, revised, and resubmitted.]

Also as part of the Galapagos experiment we collected aerosol samples for an SEM and TEM study by Dr. Jim Anderson and co-workers at Arizona State University. These samples have been analyzed and the results will complement our microprobe study. The TEM single particle study will provide unique information on the ultrafine marine aerosols, including their reactivity and aging (see Posfai et al. 1994 for results from a similar study on aerosols collected in 1990 in the EQPAC study region).

JGOFS Arabian Sea Experiment.

As part of the JGOFS field work in the Arabian Sea, aerosol samples were collected on 9 of the R/V Thompson cruises during 1995 and analyzed by neutron activation analysis (NAA) for trace metals and other elements. An initial draft version of the NAA data for these samples has already been sent to the JGOFS-Arabian Sea data archive at WHOI (<http://www1.whoi.edu/jg/dir>). Again we had intended to use SeaWiFS images to compare to the aerosol observations and the productivity measurements that were being made by other JGOFS investigators. Instead

we are using AVHRR images to map aerosol distribution and Landsat images to map out the desert source areas around the Arabian Sea region. We are also calculating air mass back trajectories for the Arabian Sea, using output from the National Weather Service Medium Range Forecast model, so that we can track the path of the air masses that move the dust out over the ocean. [Two papers (Tindale and Pease, 1997; Pease et al., 1997) have recently been submitted from this Arabian Sea work.]

IGAC Southern Ocean ACE-1 Experiment:

As part of the preparatory work for the IGAC Aerosol Characterization Experiment (ACE-1), Capt. Greg Giandomenica (USAF) studied aerosol distributions over the Australasian region using archived CZCS data. This was his thesis research as part of his MS degree in Meteorology (Giandomenica, 1995). The goal of his study was to use the seven year CZCS data set (1979-1986) to characterize atmospheric aerosol distributions over water in the Australasian region (of course the original goal was to use SeaWiFS data for this study). In his study he related aerosol distribution to climatological synoptic weather patterns using gridded wind fields from the weather forecast models. While there are serious problems with the CZCS data set, primarily because of incomplete coverage, the satellite did record a clear relationship between the aerosol radiance and synoptic weather patterns with distinct signals over the ocean northwest and southeast of Australia. While the interpretation was limited by the lack of continuous CZCS data and with problems associated with aerosol retrievals over Case 2 waters, an aerosol climatology pattern was present and was discussed in some detail in his thesis.

The SeaWiFS funding supported one Ph.D. student, Joel Seymour, who is starting the last year of his research. He is studying the characteristics of atmospheric dust as it relates to atmospheric transport and input to the ocean. His research includes a study of the morphological, elemental, and spectral characteristics of the aerosols and some of his work is related to the ocean color sensor aerosol signal. He is also directly measuring solar irradiance with a spectroradiometer to quantify aerosol absorption in the troposphere compared to the stratosphere. The bulk of the support we are requesting in our final year renewal [which became a new grant] is for Mr. Seymour, to continue his student assistantship, so that he can finish the Macquarie Island field work and complete his degree.

Last year we purchased a spectroradiometer for use in the field to measure sky radiance values. We also intend to use this instrument in the laboratory to measure aerosol transmittance and reflectance on archived samples. For this, we have ordered, and just received, an integrating sphere so that we can directly measure the absorption and scattering of the particles while on the air sample filters. We thus hope to "spectrally" characterize the

different types of aerosol samples that we collect/have collected in each region. This is work that we are just starting and will probably be ongoing past the end of our SeaWiFS grant.

In summary, we have almost completed three years of atmospheric sampling, with participation in 11 separate experiments. The final year of our study will be spend finishing the chemical and single particle analyses, analyzing the data, and publishing the results. We also anticipate that the remaining student supported by this study, will have completed his Ph.D. by next summer.

[Joel Seymour's dissertation defense exam is already scheduled for January, 1998].

Publications:

Giondomenica*, G. (Capt., USAF). Aerosol Analysis with the Coastal Zone Color Scanner (CZCS): The Australasian Region. MS. Thesis, Dept. of Meteorology, Texas A&M University, 1995.

Martin, J.H., et al. (including N.W. Tindale), 1994. Testing the iron hypothesis in ecosystems of the equatorial Pacific Ocean. *Nature*, 371(6493): 123-129.

Posfai, M., J.R. Anderson, P.R. Buseck, T.W. Shattuck and N.W. Tindale. Constituents of a remote Pacific marine aerosol: A TEM study. *Atmospheric Environment*, 28(10), 1747-1756, 1994.

Seymour*, J.C. and N.W. Tindale. X-ray mapping techniques applied to the characterization of atmospheric particles. Submitted to *J. Micros. Soc. Amer.*, August 1996. [Note: "The Journal of Micros. Soc. Amer." Has changed its name to "Microscopy and Microanalysis" during the last year and our paper got caught-up in the editor change and renaming, hence the "revised" reference below!]

X-ray mapping techniques applied to the characterization of atmospheric particles. J.C. Seymour* and N.W. Tindale. Submitted to *Microscopy and Microanalysis*. (Reviewed, revised and resubmitted, August 1997.)

Aerosols over the Arabian Sea: Atmospheric transport pathways and concentrations of dust and sea salt. N.W. Tindale and P.P. Pease*. Submitted to *Deep Sea Research* special issue, September, 1997. (Under review.)

Mineralogical identification and transport pathways of dune sand using Landsat TM imagery, Wahiba Sand Sea, Sultanate of Oman. P.P. Pease*, G.D. Bierly, V.P. Tchakerian, and N.W. Tindale. To be submitted in Nov. 1997.

(* - Graduate students from my group)

Presentations:

Mineralogical Identification of Dune Sand using Landsat TM Imagery, Wahiba Sand Sea, Sultanate of Oman. V.P. Tchakerian, G.D. Bierly, P.P. Pease*, and N.W. Tindale. Association of American Geographers 93rd Annual Meeting, 1-5 April 1997, Fort Worth, TX. (Abstract: AAG Newsletter, 263, March 1997.)

Desert Aeolian Dust Transport into the Arabian Sea. P.P. Pease*, V.P. Tchakerian, and N.W. Tindale. Association of American Geographers 92nd Annual Meeting, 9-13 April 1996, Charlotte, North Carolina. (Abstract: AAG Newsletter, 232, March 1996.)

Transport and Input of Aerosol Material to the Surface Waters of the Equatorial Pacific in Relation to "The Iron Hypothesis". N.W. Tindale. AGU/ASLO Ocean Sciences Meeting, San Diego, California. February 12-16, 1996. (Abstract: EOS 76(3), OS154, 1996.)

Sources, transport, input and effect of mineral aerosols over the Arabian Sea. N.W. Tindale. Depts. of Chemistry and Geology, Sultan Qaboos University, Muscat, Oman. January 2, 1996.

SEM techniques in the study of atmospheric aerosol particles. Seymour, J.C.*, R. Guillemette, and N.W. Tindale. Microbeam Analysis Society Meeting, New Orleans, LA, 1-5 August, 1994. **(This paper received the MAS Distinguished Scholar Award for Students for 1994).**

The Martin Iron Experiments: Overview and Iron Chemistry. Coale, K., T. Coley, V. Elrod, S. Fitzwater, M. Gordon, C. Hunter, K. Johnson, J. Nowicki, S. Tanner, A. Anderson, C. Collins, T. Stanton, J. Stockel, C. Law, R. Ling, M. Liddicoat, K. Van, Scoy, A. Watson, R. Barber, S. Lindley, R. Bidigare, M.M. Latasa, M. Ondrusek, K. Lee, F. Millero, W. Yao, J. Zhang, G. Friederich, C. Sakamoto, P. Falkowski, R. Greene, Z. Kolber, J. Seymour*, N. Tindale, A. Hatton, P. Liss, P. Nightingale, S. Turner, S. Chisholm, F. Hoge, R. Swift, W. Wright, J. Youngal, M. Lewis, R. Wanninkhof. American Geophysical Union Meeting, San Diego, CA, 21-25 February, 1994.